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12 Simulation in medical education—phantoms in medicine

12.1 Introduction

The dictionary prepared by the Society for Simulation in Healthcare has defined simulation as a technique that creates a situation or environment to allow persons to experience a representation of a real event for the purpose of practice, learning, evaluation, and testing or to gain understanding of systems or human actions [1].

Simulation plays an important role especially in the process of learning new skills. Thanks to the controlled environment, the learner has the opportunity to safely acquire and improve skills by repeating it without the consequences of potential error. Especially in medicine, this risk translates directly into the life and health of patients.

The optimal way to acquire complex skills is described by “the circle of learning.” The process starts with the acquisition of knowledge related to a topic. Next in simulated conditions, the trainee acquires simple skills related to the implementation of the complete procedure. In the times of dynamic development of computer simulation, the next step might be an exercise based on computer programs or more advanced virtual reality techniques (serious gaming). The final stage of the simulation is to perform the task in conditions that reproduce as closely as possible an actual workplace (high-fidelity simulation).

A good example of such a process is learning how to perform cardiopulmonary resuscitation. Students first learn the knowledge necessary to understand the principles of resuscitation. Then, using simulators, they practice simple skills such as chest compressions, ventilation with a self-inflating bag and a face mask, securing airways procedure, intravascular access, ECG interpretation, and defibrillation. Procedures are learned separately, and the number of repetitions ensures mastery of basic skills. In the next stage, students might use computer programs simulating the work of the resuscitation team, in which students learn how to coordinate the work of members of the resuscitation team, control time, and carry out appropriate activities in accordance with the algorithm of advanced life support (ALS). Finally, the last stage is applying the principles of the reanimation team in simulated clinical settings where the additional difficulty is working in a real therapeutic team. Usually, at this stage, the group realizes that the ability to efficiently and correctly perform individual tasks detached from the whole task does not mean that the same procedures will be properly performed during more complex activities, i.e., in this case, the work of the resuscitation team performing a relatively uncomplicated ALS algorithm. Simulated clinical conditions allow the acquisition of new skills such as communication in a therapeutic team, team management, work as a team member, therapeutic decisions, and situation awareness.

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12.2 Full-body simulators application in the training of medical personnel

12.2.1 History

The first full-body simulators were used in the education of nurses at the beginning of the 20th century. In 1911, the first full-length simulator was produced, which intends to be used to learn nurses' patient care [2]. Hartford Hospital approached the Rhode Island doll manufacturer M.J. Chase Co. to design the first manikin tailored for health care practice. Modeled and named after her creator, Martha Jenks Chase, Mrs. Chase since then, patient simulators have permanently found their place in laboratories where the basics skills of nursing were taught. The next step in the development of patient simulators was the publication of the articles that describe the standards of doing modern cardiopulmonary resuscitation and the creation of the first simulators designed to learn these skills in the 1950s by professors Peter Safar, William Kouwenhoven, and their collaborators. With the development of computers, simulators became more and more complex. They enable students to learn relatively simple skills such as patient care or chest compressions and ventilation. The first, computer-controlled, advanced patient simulator was developed in 1969 Sim One [3]. The mannequin replicated physiologic responses such as chest movement in respiration, blinking eyes, and pupils that have opened and closed. Sim One also had heartbeat, temporal and carotid pulse, and blood pressure. The simulator was developed by Dr. Stephen Abrahamson and Dr. Judson Denson and their team. The simulator was originally meant to be used mainly to train anesthesiologists. At the end of the 1980s, the next generation of patient simulators, controlled by PC computers, appeared. MedSim Eagle from 1986 already had almost all functions currently available in modern patient simulators: the ability to auscultate heart tones and respiratory murmurs, speaking with the help of a built-in loudspeaker and advanced hemodynamic monitoring. The further development of patient simulators was closely related to the development of computers, the miniaturization of equipment necessary to control, and the function of the simulator or wireless communication. Modern patient simulators are advanced robots that enable both history taking and physical examination of the simulated patient as well as performing numerous invasive procedures.

In this way, three basic types of full-body patient simulators were created to teach patient care, advanced cardiopulmonary resuscitation, and advanced patient simulators that you can use for clinical simulated scenarios.

12.3 The capabilities of different types of simulators

As mentioned before, technical skills training led to the development of full and partial body simulators. They remain the main way to improve technical competence in health care until today. There are some changes, mainly in the technical side of the hardware and software, but the main idea remains the same.

There is a vast number of simulators available commercially and more are in the development. As assessed in 2014 by Stunt et al. [4], there are more than 400 devices on the market excluding those used for demonstration purposes or knowledge transfer.

The basic principle is that we replace the whole body or a part of the body of the patient with an artificial device mimicking representative qualities. Because this chapter is devoted mostly to full-body simulators, we will concentrate on those. Partial body simulators will be mentioned only briefly to create a context.

12.3.1 Partial body simulators

They range from simulated skin pads to torso with or without head. Skin pads are used to teach/learn subcutaneous injections or skin incision, small excisions, and stitching. Slightly more elaborate simulators would depict part of the body like a limb or buttock to train intravenous (IV) access or intramuscular injections. All those simple task trainers can be either very simple or fairly complicated devices with lots of electronics or complicated mechanical or hydraulic parts to either give feedback on the quality of performance or to better emulate the reality. Hydraulics may include pipes representing venous or arterial vessels, urinary tract, or airways. They may depict normal body parts or pathological like fluid or air collections in chest drainage task trainers.

Feedback given by devices can also range from none to very elaborated assessment of quality of performance. Basic feedback can be delivered by simulated aspiration of air or artificial blood as a way to prove acceptable performance. More advance models may serve similar purposes but be as complicated and technologically advance as virtual reality injection simulator [5]. They provide numerical feedback on many aspects of performance, which may include but are not limited to timing, range of movement, or its linear or angular velocity. Of course, there are some models available, which provide some feedback related to set standards. Be it in the form of color-coded feedback (i.e., green for good, red for suboptimal performance) or any form of numerical or graphical representation.

One should also mention that some of the partial body simulators are meant as stand-alone devices while others as wearables enabling hybrid simulation with use of simulated/standardized patient (trained actor/lay person/patient) and partial body simulator at the same time. Examples would include wearable injection pads, breast models for physical examination, or even a full torso vest, enabling abdominal or thoracic surgical procedures in real time with blood pumping devices and artificial internal organs [6].

All the above-mentioned simulators are meant to give the caregiver a chance to perform tasks as closely resembling his/her future job as possible. However, there is also a need for empathy development, not only for technical skills enhancement. Here simulators help too. These are almost always wearables aimed at simulating different impairments so that future health care providers can experience limitations of handicapped people and thus understand them better and possibly identify a bit more with them building up the empathy and providing more emotion oriented care. These would include age simulators, eyesight, or hearing impairment simulators, pregnancy simulators, and many others.

Examples of partial body simulators include but are certainly not limited to the following:
- skin flaps to practice small surgical skills, suturing, and injections
- arm and forearm with hand for IV access
- head and neck for airways management
- upper torso and neck for large blood vessel access
- torso for pleural drainage or pneumothorax decompression
- legs for immobilization
- shins and arms or isolated respective bone structures for intraosseous access
- eyes and year to practice examination
- different body parts for decubitus management, bandaging and wound debridement, and dressing
- stoma care trainers (ileostomy, colostomy, urostomy, and gastrostomy)
- patient handicaps simulation (aging, eyesight and hearing loss, pregnancy, etc.)
- wearable simulators

12.3.2 Nursing care simulators

Nursing care simulators are designed mainly to teach technical skills that nurses should learn to properly care for patients, in particular, learning invasive procedures. Mastering such skills in the first place on simulators increases the safety of patients because the nurse for the first time performing a given procedure in a hospital setting has already acquired the basic skills at the simulation center.

Essential components of nursing care simulators are as follows:
- Full mobility of the joints and the body allowing simulate of real human movements
- Possibility to set the simulator in a lying and sitting position
- Anatomical points palpable for proper application of patient care (e.g., collarbone, sternum, and pelvic bones)
- Weight close to the weight of a real patient
- The ability to perform care procedures, such as
  - rinsing and cleaning the ears
  - removable dentures for learning oral hygiene and dentures
  - inserting the nasogastric tube and gastric lavage
  - tracheostomy care and suction from the respiratory tract
  - performing intravascular access, intramuscular, subcutaneous, and intradermal injections
  - intravenous medication and fluid infusion

  - care of the vascular port, central venous access, etc.
  - care for gastrostomy, colostomy, and nephrostomy
  - bladder catheterization
  - enema training
  - measurement of blood pressure
  - other

Most of these skills can be trained on task trainers, and in some learning situations, it is important to perform with a range of procedures on the same mannequin. Learning on full-body simulators increases the realism of simulation and allows participants to combine several different skills while training the care of a simulated patient, including nontechnical skills and teamwork.

12.3.3 Advances life support full-body simulator essential properties

The knowledge and skills of cardiopulmonary resuscitation is an important element of the medical staff training process. Every person working on patients should have at least basic resuscitation skills. Simulators from this group enable learning both basic and ALS skills.

The essential components of basic life support simulator are as follows:

- Lifelike anatomy allowing learning resuscitation
  - Perform nose-pinch, head tilt, chin lift, and jaw thrust
  - Ventilation (mouth to mouth, mouth to nose, self-inflating bag)
  - Chest compressions
- System designed to provide information about the quality of resuscitation might include several parameters, including but not limited to the following:
  - Ventilation volume
  - Correct ventilation percentage
  - Chest compressions depth
  - Chest compressions frequency
  - Correct chest compressions percentage
  - Compression to relaxation ratio
  - Information about wrong hands positioning on patient chest

In addition, advanced support simulator should include elements that enable additional procedures:

- Advanced airway management skills
- ECG monitoring and interpretation
- Defibrillation
- IV line insertion
- IV medicaments injections

That kind of equipment is used in training the resuscitation skills of teams and allows them to perform all standard procedures included in the ALS protocol.

12.3.4 Advanced patient simulators

Simulators of this type are used during high-fidelity simulations. High-fidelity simulation is defined as experiences that are extremely realistic and provide a high level of interactivity and realism for the learner.

These simulators usually include all functions that are incorporated to ALS training manikins. Components of advanced patient simulators might vary and depend mainly on simulator price. During exercises with an advanced patient simulator, the team usually is able to perform the following:

- Securing airways using simple and advanced airway devices, including intubation and cricothyroidotomy
- Suction oral cavity and airways
- Oxygen therapy
- Ventilation using bag valve mask or ventilator
- IV or IO line insertion
- Medicament infusion
- Blood pressure measurement
- Advanced vital signs monitoring (including SpO_2, $ETCO_2$, invasive BP, etc.)
- Urethral catheterization
- Chest needle decompression
- Chest drain insertion

Patient simulator also allows physical examination and assessment of the following:

- Risk of airway edema
- Breathing rate
- Chest wall movement
- Lung sounds
- Heart sounds
- Bowel sounds
- Pulse on central (carotid and femoral) and peripheral (radial) arteries
- Pupils reaction to light
- Skin moisture
- Fluid leakage from ears, nose, mouth, and eyes

This type of simulator is most often used to learn teamwork in life-threatening situations of the patient, when it is necessary to perform numerous interventions, including invasive procedures, at the same time. High-fidelity simulation is also used to learn nontechnical skills.

12.3.5 Virtual reality and enhanced reality simulators

Technically speaking, they are not full-body simulators because per definition in virtual reality, there is no physical equipment at all (except from the computer and some sort of optical system), and for enhanced reality simulators, body parts are mostly simple plastic dolls. However, if we approach the topic cognitively by asking what sort of the work they do and what competencies they help to develop, it becomes clear that they belong to this section.

12.3.5.1 Virtual reality

These simulators take trainees to a nonexistent reality, which helps them to develop skills based on some simulation of respective sensory input. The most obvious one is visual simulation by means of monitors, goggles, or helmets. In the gaming industry, these also provide some sensory information by means of force feedback with especially designed vests. In medical training, force feedback is mostly limited to virtual reality surgical simulations, where force feedback simulates interaction between surgical tools and body parts or instrument collisions [7, 8].

There are numbers of uses for these devices. Developers reproduced almost all basic laparoscopic skill drills and a number of surgical procedures. The experience is still very different from reality, but research proves them to be effective training tools. The pricing of these devices is still a limiting factor, but that will probably be resolved in the future with market expansion and technological advances in consumer market. One unique feature of virtual reality surgical simulators is their ability to assist procedural training (not drills and basic skills only). The trainee can practice steps of real procedure in a gamelike fashion. These include but are not limited to laparoscopic cholecystectomy, gynecological laparoscopic procedures, or colorectal surgery. Apart from laparoscopy, a number of other virtual reality training tools are available on the market. Open orthopedic surgery VR trainers (some with tactile feedback delivered via VR gloves), arthroscopy, neurosurgery, maxilla-facial surgery, spine surgery, or endovascular surgery are the examples of disciplines where VR has a strong foothold. The number of these disciplines and available products grows daily. Advanced surgical manipulators (often called surgical robots) also have their respective simulators, making it certainly easier to transfer skills from open or laparoscopic surgery to robotic cases [9, 10].

12.3.5.2 Enhanced/augmented reality

Physical interaction with reality is very difficult to simulate virtually. It would require full-body suites with sensory input for tactile, pressure (weight), auditory, and visual stimuli. By contrast, physical simulators lack reality in some aspects like human-human interaction, nonverbal communication, face mimics, or movement. It is also very time consuming to moulage (apply characterization makeup) the physical simulators. It is also a very big organizational effort to simulate the environment that plays a key role in high-fidelity, ultrarealistic training.

Here enhanced reality originally introduced for military purposes (Virtual Fixtures for U.S. Air Force) later made its way to other industries, including fashion, sales, e-commerce, advertisement, transportation (augmented reality navigation systems), education, and health care. The obvious reasons are that it could possibly take the best of both worlds. Tactile, proprioceptive (positional), and partially audio and visual sensory input could be supplemented with additional sensory information. Currently, it is mostly visual because of the dominance of that sensory mode in humans, but other senses that are experimented with include smell or audio [11–13].

The modes of delivery of these modified sensory inputs are numerous, and they include head-mounted eye glasses, helmets, goggles, direct retina display devices, and others. One must also remember that sometimes it is the group rather than the single user that needs to have sensory input modified. For this situation, spatial augmented reality systems are developed, and they include projectors, lights, speakers, and smoke simulators to modify the environment rather than the single user sensory input.

12.4 Nontechnical skills training

The aim of this chapter was to shortly present topics related to training in the field of nontechnical skills for people working in therapeutic teams (trauma team, resuscitation team, etc.). This type of exercise should be a compulsory part of the curriculum of medical students and postgraduate training, not only doctors but also nurses, midwives, paramedics, and other people who in the future after graduation will operate in the conditions of a multispecialized therapeutic team.

12.4.1 Crisis resource management

Crisis resource management (CRM) is a set of procedures and rules for use in environments where human error may have disastrous consequences. It enables the optimal use of all available resources (people, procedures, and equipment), which increase the safety and effectiveness of actions in a crisis, thanks to the decreasing numbers of errors due to the human factor [1].

Human factor is the discipline or science of studying the interaction between humans and systems and technology; it includes, but is not limited to, principles and applications in the areas of human engineering, personnel selection, training, life support, job performance aids, and human performance evaluation (M&S Glossary) [1].

Creating the basic principles of CRM, you can base yourself on the following skill list:

- Situation awareness
- Planning and decision making

- Teamwork skills
- Team leader skills
- Communication

12.4.1.1 Situation awareness

Situation awareness is the ability to continuously collect data from the environment in relation to the situation in which a person is located, enabling the identification and interpretation of changes taking place in the environment and predicting their effect in the near future.

In short, this means seeing and knowing what's going on and predicting what's going to happen next.

The three elements/levels of situational awareness are as follows [14]:

- Perception of elements of the current situation
- Understanding/creating an image of the current situation (mental model)
- Anticipating options that will be possible in the near future/what will happen in a moment

12.4.1.2 Cognitive errors

Problems at any of the three stages of creating situation awareness can cause a cognitive error. As a result of incorrect data collection or interpretation, the team make decisions and takes actions that are inadequate to the situation.

When investigating adverse events in aviation, Mc Carthy stated that the occurrence of a cognitive error usually occurs in situations when [15]

- the attention is too focused, which in effect leads to receiving only a part of the information—31% of the investigated events;
- the attention is dispersed by factors unrelated to the task being performed—22% of the investigated events;
- the tasks performed are too complicated to the level of training of people participating in it—17% of investigated events;
- the team focuses on one activity and omits or refrains from performing other tasks important from the point of view of patient safety—17% of the investigated events.

This leads to dangerous situations. The doctor may be convinced that he has made a correct diagnosis and started treating the patient, although the cause of the problem is completely different (this and only this).

In the case of a fixation error such as "all but not this," the doctor takes into account several possible options but excluding one as impossible, usually out of fear of its consequences.

Another relatively common cognitive error includes the situation on the team's conviction about the absence of a threat, although the situation requires immediate action to overcome the actual real life or health threat (everything is fine). A typical example of this situation is an adverse event described in the YouTube movie *Just*

Routine Operation, where the lack of situation awareness was one of elements of an adverse event that led to the patient's death as a result of hypoxia.

12.4.1.3 Planning and decision making

Decision making is a process of gathering and processing information, which results in a nonrandom selection of one solution to the problem from at least two or more available solutions. The decision-making process has been in the field of interest for both scientists and practitioners for many years. The effect of this was the development of tools to facilitate the decision-making process.

Typically, decision making involves successive actions as follows:

– Assessment of the situation
– Development and consideration of one or more action options, selection of one option
– Implementation of the decision
– Evaluation of the effects of the action taken and implemented

One of the ways to support the decision-making process is to describe the next steps of the process with the letters of the acronym, e.g., the DODAR acronym used by British Airways pilots:

D, detect—We detect the problem. The patient's blood pressure falls.
I should collect data. When was the last time this parameter was observed/measured? What happens to other vital signs? (Does the respiration rate increase or decrease?) The monitor may have broken down or the measuring cuff has moved—it must be "detected."
What are the possible reasons for this situation? What have we done to prevent it so far?

O, options—In understanding the problem, we have to consider options.
We consider possible options together with the team. What are the possibilities of conduct? How do you find the cause of the pressure drop? How do you treat a patient?

D, decision—We make a decision.
As the person managing the team, we must decide at some point what we are going to do, what is the plan.

A, actions/assignments—These are tasks/work assignments.
We inform the team what the plan is about and what we will do. We will share tasks.

R, review—When the plan is implemented, at the first opportunity, when we have a few seconds break, we are reviewing the situation. Did we remember everything? What else can you do?

12.4.2 Teamwork

Management of patient in a life-threatening situation usually requires the work of a team of people. The team consists of people with different experiences, skills, and abilities working together to increase the chance of effective treatment of the patient.

Proper teamwork can have a significant effect on the final result of patient treatment.

What makes a team efficient?
- Individual team member’s skills
- Proper task distribution
- Work coordination
- Good team leader
- Communication skills
- Motivation

12.4.2.1 The 10-seconds-for-10-minutes technique—sharing decision making

Working in a team gives a unique opportunity to use the knowledge and skills of all group members during the decision-making process. This action has certain consequences. Lack of information may result in different, often contradictory, ways of solving the problem they are experiencing by different team members.

Passing all the necessary information to all team members might require a short break in activities (stop) [16], during which team members share their information and jointly conduct an assessment of the situation. The effect of such an exchange of views should be to jointly establish a list of problems that the team encounters at a given moment, set priorities, and decide on actions to be taken in the near future.

It is true that ultimately the team leader will accept the decisions made, but at the same time, it should be remembered that obedience to the superior, an excessive desire to please others, and giving someone else’s opinion over their own could lead to an adverse event.

12.4.2.2 Team leader skills

Team leaders appear everywhere where groups of people are used to carry out tasks. One of their main tasks is to ensure the effective functioning of the team.

A team leader is a formally or informally chosen person whose tasks consist of
- management and coordination,
- motivating to work together,
- evaluation of activities,
- planning and organization of work—setting priorities,
- ensuring a good atmosphere in the team [17].

12.4.2.3 Communication

Communication in large part is responsible for the correct teamwork, somehow linking all the previously described elements. It is defined as transmitting and receiving information between two or more people. We can also define communication by answering four questions:
- What—information transfer
- How—the way communication is conducted
- Why—the reason for communication
- Who—communicating persons

During simulation, we can teach participants how to communicate properly and give them few relatively easy skills that make communication better.

12.4.2.4 Close loop communication

Close loop communication involves interaction between the sender and the recipient. In this system, the person who is the recipient of the information processes it and then transfers it back to the sender.

Example:
Team leader: Piotr, inject 1 mg of adrenaline intravenously.
Piotr (team member): I'm going to give 1 mg of adrenaline intravenously.

Such a way of communicating may take a bit more time, but it is more effective and safe. The sender is calmer hearing the feedback from the recipient. The recipient also feels more confident knowing that the sender has checked whether he has properly heard and understood the information.

12.4.2.5 Team member's name use during communication

The message may not reach the team member simply because he is not expecting it, he is busy carrying out ordered tasks, or he is wondering how to optimally solve the situation. The reason for the failure to perform the task may also be in the way it is formulated; for example, the "we should give morphine" command will most probably not be done because it is not known to whom it is addressed or can be interpreted as a question of opinion or thinking aloud. When formulating requests or commands, you should always start them with the name of the person to whom the message is addressed, and it may be accompanied by nonverbal communication (e.g., looking at him, touching him); e.g., Piotr, give 1 mg of adrenaline intravenously.

12.4.2.6 Team assertiveness

Each team member should be able to speak their opinion openly, also when their point of view does not agree with the team leader's point of view. The ability to take such a tactful and effective message is crucial to the safety of teamwork.

The message “I think we are going a bit too low” may not have the proper effect when the plane is several dozen meters above the ground and height continues to decrease.

In simple situations in which the decision of the team leader is in conflict with the organization of work in the ward or guidelines, the question “Are you sure?” might be enough to correct a decision. If there is no reaction, you can take further steps to solve the problem. Constructing subsequent statements can be based on proven assertiveness grading schemes such as CUSS or PACE.

CUSS
- C, concern—I am concerned that ...
- U, unsure—I’m not sure that ...
- S, safety—It is not safe.
- S, stop—Stop it immediately.

PACE
- P, probe—Did you know ...? I do not understand why you want to do it.
- A, alert (vigilance)—I think that your decisions will cause ...
- C, challenge—Your actions will hurt because ...
- E, emergency action—Stop it immediately! For the sake of the patient, we should ...

12.4.3 Technical skills training

As mentioned previously, technical skills training led to the development of full and partial body simulators. They remain the main way to improve technical competence in health care until today, and they are very likely to stay with us much longer. There are some changes, mainly in the technical side of the hardware and software, but the main idea remains the same.

The basic principle is that we replace the whole body or a part of the body of the patient with an artificial device mimicking representative qualities. Because this chapter is devoted mostly to full-body simulators, we will concentrate on those.

The basic principle of training of any technical skill with any sort of simulator is that the costs of training (understood not as monetary costs but also as organizational costs, risk management, possibility of injury to the trainee or the subject of procedure, cognitive and emotional challenges, and all possible other material or immaterial costs) must be lowered so that it makes training easier to be applied many times to increase the performance in real situation. One must also keep in mind that the frequency of utilization of a particular skill in real life must be taken into consideration. For these rarely performed tasks requiring high skills, simulation might be the only method to achieve competence. An easy example comes from the aviation industry: emergency landing procedures in case of failure of some of aircraft’s systems is better not to be practiced first time in reality with 335 passengers on board Boeing 787 Dreamliner. It is possible to reliably simulate these events on demand in a safe training environment. The same principle is applied in medicine. Some of the most widespread examples are BLS and ALS training programs. Majority of trained personnel will not perform practiced skills at all or will do that very rarely, making simulation the main way to acquire and maintain the skills.

Safety consideration applies to both sides of that equitation. Simulation-based training makes personnel more technically apt but also gives the trainees so much needed self-confidence and possibility to avoid putting ones training above the safety of patients [18].

As far as utilization of training devices go, a typical approach is to use step-up training modes. Initially, trainees receive information (knowledge transfer) on how a procedure should be performed. That is passed by means of live or recorded demonstration, text, drawings, or any other way known in knowledge transfer. The second step includes explanation of optimal performance, and the third step includes one practice preferably with some sort of feedback or correction from the trainer. Several methodologies have been developed to enhance the effectiveness of training [19].

12.4.3.1 See one, do one, teach one

It is one of the most popular and also one of worst understood modalities. Often incorrectly used as a synonym of an easy task as in “this is so easy you can have a look once, then you can do it alone and next time you can teach it.” The real reasoning behind this method is that you need to see something done first, and then you should do it yourself; once you are able to teach it, that is when you really know how to do it. For simple tasks, it is really effective and it also improves trainee engagement because they are given bigger responsibilities. The ability to teach in this case means not pedagogical skills but sufficient understanding and proper acquisition of manual competence to demonstrate and explain.

12.4.3.2 Peyton four-step approach

Based on cognitive sciences, a system for the optimization of technical skills transfer has been developed [20]. It is a bit more elaborate and probably more effective. It includes four steps:

1. Demonstration
2. Deconstruction
3. Comprehension
4. Execution

In the first step, students should observe a real-time, real-speed demonstration of good quality performance without any distraction, breaks, or explanations. The reason is for students to be able to have a clear reference regarding the expected standard of performance.

In the second step, students should see the procedure one more time, but this time with comments and explanations. This step is meant to clarify all doubts, explain the crucial moments, and point out crucial steps.

In the third step, students should aim at understanding all steps and ways to perform. In reality, it is often done in a way that while an instructor performs a third demonstration, one of students describes the crucial steps.

In the fourth step, the student performs by himself. This step can be used for the next student to perform step 3.

This sequence enables the utilization of different modalities of learning. In the first step, it is visualization and time stamping (realization of timing of the procedure). In the second step, it is auditory learning. The third step is verbalization, and the fourth one is using kinesthetic memorization.

Peyton's four-step approach requires careful planning of the teaching session. First, a skill to be taught must not take too long to demonstrate. Simple technical procedures like BLS, IV line placement, or simple airway management are most commonly taught that way. Second, it is important to think through your explanations carefully. What is done in step 2 must not be too complicated, should be easy to remember, and should easily trigger the next step. It is meant to help students perform, and he/she must remember it at one go. If the procedure needs more explanations, either it is not the best choice for this method or the explanation should take place in a form of lecture or other knowledge transfer method before skill practice.

The model is flexible enough that it can be adapted to other tasks. It is being used (intentionally or not) in training some complex technical skills like surgery. For the first few cases, the trainee observes, receives explanation, asks and answers questions, does probe understanding, and then finally performs. This is just but one modification of numerous published practices throughout the world.

12.4.3.3 Slicing method/skill deconstruction

Some fairly complicated tasks are difficult to teach, especially to larger (5–20) groups of trainees when demonstrated and explained. One needs to break them into much smaller, "digestible" parts. It is usually one specific move that is being demonstrated after another. It helps to have them named ("word coded"). Individual moves are merged into sequences and then whole tasks. A useful analogy would be teaching dancing. First, trainees learn steps, then figures, then predefined choreography, and only then they improvise.

That method can be easily adapted to teaching larger groups of people with diverse starting points or different manual dexterity. Slices are cut down to the level of the person with the lowest skill and tempo of progress to the level of the slowest learner. That way, the whole group can be taught with limited resources, but of course the potential of the fastest learners or people with the highest skill on entry is not used properly.

12.4.3.4 Programmatic teaching of technical skills

It is important to plan skill acquisition into the course, the subject, or the whole training curriculum. It is known that teaching in any domain (knowledge, technical, or nontechnical skills) is best done when new competencies are built on the previous ones. This helps retention and increases the tempo of acquisition. It is of course no different for technical skills. Most teachers agree on the step-up approach. The trainee starts with small, isolated skills and then merges into more complex tasks to progress to full procedures. Often, this step is followed by merging several procedures to be performed in proper sequence. At different stages, some nontechnical skills are usually blended because technical competence alone is very often not sufficient in today's world. Training of these nontechnical competences has been described in Chapter 12.4.

The typical sequence could include a simple station to teach an assembly of IV access kit followed by a task trainer (an IV access arm). Once students are reasonably fluent with this, an advanced full-body simulator and a simple clinical scenario where students have to perform an IV access can be used. Later stages may include a hybrid simulation with IV access after they explain the procedure and obtain informed consent form a simulated patient to finally arrive to a high-fidelity simulation where IV access is but a small task within reach simulated workplace experience.

This progress in training is essential to keep students' engagement at high levels and also to properly adjust the level of training to trainees' abilities and needs.

12.5 Summary

Full and partial body simulators as well as virtual and augmented reality simulation in medical education are a cornerstone of modern training programs. They help to increase patients' and trainees' safety and also lower the costs of training and increase its effectiveness. Current trends produce more advanced equipment in all ranges of simulators, from the basic ones to the most complex, hybrid teaching environments. Teaching both technical and nontechnical skills is essential, and it can often be done in a close sequence using similar methodologies and equipment. In the future, we will probably see much more of that technological progress, especially in the field of virtual and augmented reality simulators.

12.6 References

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